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Docket No.: S1022.80494US00  
(PATENT)

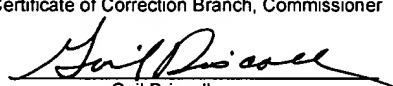
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Tomas NORDSTRÖM, Daniel BENGTTSSON, and Olivier ISSON  
 Serial No.: 09/737155  
 Filed: December 14, 2000  
 Serial No.: 09/737,155  
 For: DSL TRANSMISSION SYSTEM WITH FAR-END CROSSTALK CANCELLATION  
 Examiner: Emmanuel Bayard  
 Art Unit: 2631

Issued: January 17, 2006  
 Patent No.: 6,987,800 B2  
 JAN 27 2006

**Certificate of Correction**

Confirmation No.: 8195

<p align="center"><b>Certificate of Mailing Under 37 CFR 1.8(a)</b></p> <p>I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as First Class Mail, in an envelope addressed to: Attention: Certificate of Correction Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.</p> <p>Dated: January 23, 2006</p>		 Gail Driscoll
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**REQUEST FOR CERTIFICATE OF CORRECTION  
PURSUANT TO 37 CFR 1.322**

Attention: Certificate of Correction Branch  
 Commissioner for Patents  
 P.O. Box 1450  
 Alexandria, VA 22313-1450

Sir/Madam:

Upon reviewing the above-identified patent, Patentee noted a typographical error which should be corrected.

In the Specification:

The equation found in column 4, line 35 of U.S. Patent No. 6,987,800, reproduced below, is incorrect.

$$\text{FEXT}(f_j) = \sum_{l=1}^n Hl_p(f_l)Sl(f_j), l \neq p$$

The same equation, found on page 6 of the application as filed is reproduced below.

$$\text{FEXT}(f_j) = \sum_{l=1}^n Hl_p(f_j)Sl(f_j), l \neq p$$

JAN 30 2006

The error, located between the second set of parenthesis, was not in the application as filed by applicant. No amendment was made by either the Examiner or Patentee changing “(ff)” to “(fl)” as it appears in the equation of U.S. Patent No. 6,987,800.

In support of this request Patentee encloses highlighted copies of page 6 of the application as filed and column 4 of issued U.S. Patent No. 6,987,800. Also enclosed is PTO form SB/44.

The correction requested does not involve change in the patent that constitutes new matter or would require reexamination. Therefore, it is respectfully requested that the corrections be made and that a Certificate of Correction be issued.

Patentees respectfully submit that, since the error for which a Certificate of Correction is sought was the result of Patent Office mistake, no fee is due. However, if the Examiner deems a fee necessary, the fee may be charged to the account of the undersigned, Deposit Account No. 23/2825. Should any questions arise concerning the foregoing, please contact the undersigned at the telephone number listed below.


Dated: January 23, 2006

Respectfully submitted,

By 

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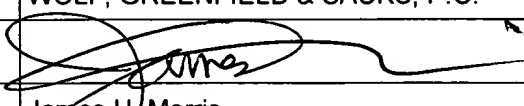
	Application Number	Patent#: 6987800 B2
	Filing Date	Issued: January 17, 2006
	First Named Inventor	Thomas Nordström
	Art Unit	2631
	Examiner Name	Emmanuel Bayard
Total Number of Pages in This Submission	Attorney Docket Number	S1022.80494US00

**ENCLOSURES (Check all that apply)**

- |   |  |  |
|---|--|--|
| <input type="checkbox"/> Fee Transmittal Form<br><input type="checkbox"/> Fee Attached<br><input type="checkbox"/> Amendment/Reply<br><input type="checkbox"/> After Final<br><input type="checkbox"/> Affidavits/declaration(s)<br><input type="checkbox"/> Extension of Time Request<br><input type="checkbox"/> Express Abandonment Request<br><input checked="" type="checkbox"/> Certificate of Correction<br><input checked="" type="checkbox"/> Request for Certificate of Correction<br><input type="checkbox"/> Reply to Missing Parts/Incomplete Application<br><input type="checkbox"/> Reply to Missing Parts under 37 CFR 1.52 or 1.53 | <input type="checkbox"/> Drawing(s)<br><input type="checkbox"/> Licensing-related Papers<br><input type="checkbox"/> Petition<br><input type="checkbox"/> Petition to Convert to a Provisional Application<br><input type="checkbox"/> Power of Attorney, Revocation Change of Correspondence Address<br><input type="checkbox"/> Terminal Disclaimer<br><input type="checkbox"/> Request for Refund<br><input type="checkbox"/> CD, Number of CD(s) _____<br><input type="checkbox"/> Landscape Table on CD | <input type="checkbox"/> After Allowance Communication to TC<br><input type="checkbox"/> Appeal Communication to Board of Appeals and Interferences<br><input type="checkbox"/> Appeal Communication to TC (Appeal Notice, Brief, Reply Brief)<br><input type="checkbox"/> Proprietary Information<br><input type="checkbox"/> Status Letter<br><input checked="" type="checkbox"/> Other Enclosure(s) (please identify below):<br>Copy of Page 6 of the Apl as Filed<br>Copy of Col. 9 of US 6,987,800<br>Return Receipt Postcard |
|---|--|--|

Remarks

**SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT**

Firm Name	WOLF, GREENFIELD & SACKS, P.C.		
Signature			
Printed name	James H. Morris		
Date	January 23, 2006	Reg. No.	34,681

**Certificate of Mailing Under 37 CFR 1.8(a)**

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Dated: January 23, 2006

Signature:  (Gail Driscoll)

JAN 30 2006

UNITED STATES PATENT AND TRADEMARK OFFICE  
CERTIFICATE OF CORRECTION

Page 1 of 1

PATENT NO. : 6987800 B2  
APPLICATION NO. : 09/737155  
ISSUE DATE : January 17, 2006  
INVENTOR(S) : Thomas Nordström, Daniel Bengtsson and Olivier Isson

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 4, line 35 should read:

$$\text{FEXT}(f_j) = \sum_{l=1}^n Hlp(f_j)Sl(f_j), l \neq p$$

MAILING ADDRESS OF SENDER (Please do not use customer number below):

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JAN 30 2006

frequency  $f_j$ .

The FEXT interference for a given frequency  $f_j$  and for a modem  $p$  can therefore be written:

$$\text{FEXT}(f_j) = \sum_{l=1}^n Hl_p(f_j)Sl(f_j), l \neq p$$

5 According to the first embodiment of the invention, the complex values  $Sl(f_j)$ ,  $l=1\dots n$ ,  $l \neq p$  are approximated by the symbols  $\hat{S}l(f_j)$ , i.e. by the symbols of the constellation coming the closest to the respective received frequency components  $Rl(f_j)$ ,  $l=1\dots n$ ,  $l \neq p$ , respectively output by the demappers 37. This implies that the processing in the modem  $p$  is one-symbol delayed with respect to the other modems.

10 The complex symbols  $\hat{S}l(f_j)$  from the other modems,  $l=1\dots n$ ,  $l \neq p$ , are then linearly combined in block 34 and subtracted by a subtractor 31 from the received frequency component  $Rp(f_j)$  to produce a FEXT-removed complex value  $Tp(f_j)$ . The demapper 37 of modem  $p$  outputs a demapped word  $\hat{X}p(f_j)$  and the corresponding constellation point  $\hat{S}p(f_j)$ . The complex value  $\hat{S}p(f_j)$  is subtracted from the complex value  $Tp(f_j)$  to produce  
15 an error value. This error value is squared in a circuit 32 and processed in a block 33 to update the coefficients of the linear combination, for example according to the known steepest gradient algorithm. The updated values stored in block 33 will be used for FEXT canceling the next frequency component  $Rp(f_j)$ , i.e. the frequency component  $Rp(f_j)$  of the next incoming block. After a few iterations, the linear combination coefficients converge  
20 towards the values  $Hlp(f_j)$  of the transfer matrix.

We have considered above FEXT cancellation at a single tone  $f_j$ . It is clear however that the processing should be repeated for all the tones  $j=1$  to  $N$ , the frequency coefficients  $Rp(f_j)$  being sequentially output by the parallel to serial converter 36. The linear combination coefficients for each frequency  $f_j$  are stored in the memory of block 33. After a  
25 few iterations the memory contains the values  $Hlp(f_j)$ ,  $l=1\dots n$  and  $l \neq p$ ,  $j=1\dots N$ .

We have assumed above that the FEXT at the different frequencies could be independently canceled. In a conventional DMT transmission system this can only be regarded as an approximation since the limited duration of the time domain blocks causes a spreading of the frequency components. Generally, the FEXT at a frequency  $f_j$  depends also

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transforming said discrete multitone signals into a discrete multitone symbol of frequency components and demapping means outputting for each frequency component the symbol of the constellation nearest thereto and the corresponding demodulated data; estimation means, in at least one line termination modem, for estimating the constellation symbols actually sent by the network termination modems, from the frequency components of the discrete multitone symbols received by all modems; calculation means for calculating a linear combination of said estimated modulated data, for subtracting said linear combination from the frequency components of said at least one line termination modem and for applying a resulting difference to the demapping means of said at least one termination modem; error calculation means for calculating the error distance between the constellation symbol from said at least one line termination modem and said difference; and updating means for updating the coefficients of said linear combination as a function of said error distance.

The invention also provides a far-end crosstalk canceling method for a digital subscriber line transmission system, said transmission system comprising a plurality of line termination modems receiving discrete multitone signals from corresponding network termination modems over a plurality of transmission channels, each line termination modem comprising frequency transforming means for transforming said discrete multitone signals into a discrete multitone symbol of frequency components, and demapping means outputting for each frequency component the symbol of the constellation nearest thereto and the corresponding demodulated data, the method comprising the steps of: estimating, for at least one line termination modem, the constellation symbols actually sent by all the modems from the frequency components of the discrete multitone symbols received by said modems; calculating a linear combination of said estimated symbols, subtracting said linear combination from the frequency components of a discrete multitone symbol and applying the resulting difference to the demapping means of said at least one modem, to obtain a constellation symbol; calculating the error distance between said constellation symbol and said difference; and updating the coefficients of said linear combination as a function of said error distance.

The foregoing and other objects, features, aspects and advantages of the invention will become apparent from the following detailed description of embodiments, given by way of illustration and not of limitation with reference to the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1, previously described, schematically shows the structure of a modem suitable for use in a DSL transmission system;

FIG. 2, previously described, schematically shows the different types of noise occurring in a DSL transmission system;

FIG. 3 shows a first and a second embodiment of a FEXT canceller according to the invention;

FIG. 4 shows a third embodiment of a FEXT canceller according to the invention;

FIG. 5 shows a fourth embodiment of a FEXT canceller according to the invention; and

FIG. 6 schematically shows the overall structure of a DSL transmission system comprising a FEXT canceller according to the third or the fourth embodiment of the invention.

#### DETAILED DESCRIPTION

The invention is based on the idea that the actual value of a symbol causing FEXT interference at the LT side can be

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obtained from the modem receiving this symbol. The modem receiving the FEXT interfering symbol and the modem receiving the FEXT corrupted symbol being both located at the central office, a connection between the two modems can be realized.

FIG. 3 shows a first embodiment of the invention and more specifically a part of the receiver TX of a modem p on the LT side, receiving a FEXT corrupted signal. In this embodiment the blocks 38 and 39 represented with dotted lines do not exist.

Each modem i on the LT side is connected to a modem c(i) on the NT side through a transmission channel. The blocks 35, 36, 37 correspond to the blocks 15, 16, 17 of the receiver RX illustrated in FIG. 1.

This first embodiment aims at canceling the FEXT interference caused by the signals transmitted by n-1 modems c(i), i=1 to n, i≠p.

For clarity purpose, suppose first that a symbol carried by the subcarrier or tone f<sub>j</sub> is FEXT corrupted by symbols at the same frequency only. If, as illustrated on FIG. 2, H(f<sub>j</sub>)=(H<sub>kl</sub>(f<sub>j</sub>)) the transfer matrix of the n transmission channels from the NT to the LT side, with k,l=1...n, f<sub>j</sub> being the frequency index with j=1...n, we can write in the frequency domain for the frequency f<sub>j</sub>:

$$R(f_j) = H(f_j) \cdot S(f_j),$$

where R(f<sub>j</sub>)=R<sub>k</sub>(f<sub>j</sub>), k=1...n, is the vector of the received frequency components and S(f<sub>j</sub>)=S<sub>k</sub>(f<sub>j</sub>), k=1...n, is the vector of the transmitted DMT symbols from the n modems, for the frequency f<sub>j</sub>.

The FEXT interference for a given frequency f<sub>j</sub> and for a modem p can therefore be written:

$$FEXT(f_j) = \sum_{l=1}^n H_{lp}(f_j) S_l(f_j), \quad l \neq p$$

According to the first embodiment of the invention, the complex values S<sub>l</sub>(f<sub>j</sub>), l=1...n, l≠p are approximated by the symbols  $\hat{S}_l(f_j)$ , i.e. by the symbols of the constellation coming the closest to the respective received frequency components R<sub>l</sub>(f<sub>j</sub>), l=1...n, l≠p, respectively output by the demappers 37. This implies that the processing in the modem p is one-symbol delayed with respect to the other modems.

The complex symbols  $\hat{S}_l(f_j)$  from the other modems, l=1...n, l≠p, are then linearly combined in block 34 and subtracted by a subtractor 31 from the received frequency component R<sub>p</sub>(f<sub>j</sub>) to produce a FEXT-removed complex value T<sub>p</sub>(f<sub>j</sub>). The demapper 37 of modem p outputs a demapped word  $\hat{X}_p(f_j)$  and the corresponding constellation point  $\hat{S}_p(f_j)$ . The complex value  $\hat{S}_p(f_j)$  is subtracted from the complex value T<sub>p</sub>(f<sub>j</sub>) to produce an error value. This error value is squared in a circuit 32 and processed in a block 33 to update the coefficients of the linear combination, for example according to the known steepest gradient algorithm. The updated values stored in block 33 will be used for FEXT canceling the next frequency component R<sub>p</sub>(f<sub>j</sub>), i.e. the frequency component R<sub>p</sub>(f<sub>j</sub>) of the next incoming block. After a few iterations, the linear combination coefficients converge towards the values H<sub>lp</sub>(f<sub>j</sub>) of the transfer matrix.

We have considered above FEXT cancellation at a single tone f<sub>j</sub>. It is clear however that the processing should be repeated for all the tones j=1 to N, the frequency coefficients R<sub>p</sub>(f<sub>j</sub>) being sequentially output by the parallel to serial converter 36. The linear combination coefficients for each